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ELECTRICAL MACHINE

The invention concerns an electrical machine according to the generic portion of claims 1 and 2 which consists of an air gap winding with at least one air-core coil which has no contact with return path material and each air-core coil simultaneously in the effective region of both magnetic poles. This means that each coil side of an air-core coil is in the effective field of one type of pole at the moment of maximum energy conversion and the type of pole of the two coil sides is different and complete their effects in the air-core coil (definition: two-pole air-core coil), with the field-free conductor regions between neighboring poles of the same type of pole also belonging to the coil side (definition: coil side). Two coil sides are connected directly or through conductors into a closed or open air-core coil whose portion lying in the movement of direction is very large and is therefore referred to as an inactive conductor or, if it lies outside the field, generally as a winding head.

These machines are known in the form of rotating machines with a radial magnetic field, e.g., in DE PS 973 746, as a bell-shaped rotor motor in which the air gap is between the shell sides of two nesting cylinders, with the outer one being a hollow cylinder, is penetrated by a radial magnetic field, and in which the air-core coils each extend axially and rotate relative to the cylinders, which are connected with one another.

The advantage of these machines lies in the utilization of high peripheral speeds and, in bell-shaped rotors, also in simple assembly and manufacture.

A disadvantage of them is that the inactive conductor portion within an air-core coil is very large. A further disadvantage is that the active conductor portion within an air-core coil can then only be increased by an axial extension of the winding, which, however, has its limits

due to mechanical reasons and the space problems which thus arise, and is particularly strongly restricted in bell-shaped rotors by the layering of the winding on only one side, so that their maximum output is limited to under 100 W.

Furthermore, these machines are known in a rotating form with an axial magnetic field as in, e.g., DE PS 839 062, in which the air gap is between two coaxially mounted disks of a field device delimiting an air gap, which is penetrated by an axial field and in which the air-core coils extend radially and rotate relative to the disks, which are connected with one another.
The advantage here lies in the small axial dimension of the machine.
However, the copper losses within an air-core coil are very large, because a deformation of the winding heads is present, with the winding heads close to the axle very short and those in the peripheral region of the machine unproportionally long, so that the portion of the conductor which lies within an air-core coil active to the direction of movement is small and the proportion to the inactive conductor portion is unfavorable. The active conductor portion is additionally strongly restricted in these machines, because their dimensions lead to unhandy machine diameters and, in coil rotors, to centrifugal force problems due to the large winding head masses in the peripheral region.

Furthermore, the problem exists in these axial and radial field machines that the coil and pole widths in air-core coils is closely connected with the length of the inactive portion of the conductor and/or with the copper losses within the air-core coil. In order to keep these small, only small pole and coil widths can be used, which, however, causes the disadvantage that in these high-poled machines, the poles are, on one hand, low-power, and, on

the other hand, the eddy current losses within the winding increase due to the many pole transitions. This dependence makes the design of the machines very complex and greatly restricts them.

In addition, a rotating axial field motor is known, in JP 0550083449 AA, in which the air gap exists between three coaxially mounted disks, between the central disk and each of the two outer disks, with the central disk carrying permanent magnetic poles on both faces, and every air-core coil folded multiple times around the outer edges of the central disk and extending in the air gap on both sides of the central disk in the direction of the axle and rotating relative to the connected disks.
The advantages of this arrangement are in the relatively small diameter with a relatively large axial dimension of the machine and the axial approach of the winding heads of each air-core coil on both sides. The active portion of conductor within the air-core coil is in two disk-shaped axially magnetized air gap regions and the inactive conductor regions are in the regions of each air-core coil near the axle and the peripheral region. Therefore, high copper losses are present here above all in the peripheral region because every coil side is folded twice around a thick, doubled magnetic disk, which is preferably also equipped with a return path core. In addition, the portions of the conductor in this region, highly active in and of themselves due to the high peripheral speed and significantly more effective than those in the disk-shaped air gap region, are unused. In the utilization as a coil rotor, these unused conductor regions even lead to centrifugal force problems due to the large mass of conductor in the peripheral region.

Furthermore, linearly operating machines are known, as they are illustrated for an electronically commutated coil rotor in "Small-power Electrical Motors", Helmut Moczala, p. 218,

Fig. 9.25, expert-Verlag 1993. In these machines, the air gap exists between two long, rectangular plates of a field device delimiting an air gap whose magnetic field penetrates the air gap, in that the air gap extends transversely to the direction of movement and the winding heads or inactive conductors each lie on an outer edge of the plates.
In this case, the proportion of active to inactive conductor within a two-pole air-core coil depends strongly on the width of the machine transverse to the direction of movement. This machine width is, however, strongly restricted because it would lead to unhandy machines. Therefore, the copper utilization within an air-core coil is very unfavorable here and the machines also take up a considerable amount of space.

The invention is based on the knowledge that these machines and thereby, up to this point, no electrical machines apply the ideal conditions discovered by Michael Faraday for energy conversion in the relative motion between conductor and magnetic field in regard to quality (orthogonality condition between the vectors of the conductor, the field, and the speed) and quantity (maximization of the amounts of the vectors) satisfactorily in their entirety for electrical machines with two-pole air-core coils.

This applies above all in that, within a two-pole air-core coil, the portion of conductor which is orthogonal to the direction of movement with orthogonal penetration by a magnetic field is very low.
If one wishes to improve this active portion of conductor in existing machines, this leads to impractical machine sizes and is limited due to centrifugal force and oscillation problems.
Furthermore, the quality conditions of using the conductor in high-speed regions and using the advantages of an axial approach of the air-core coil are not seen in this context.

The constructive forms of existing air-core coil machines greatly restrict the application of the ideal conditions discovered by Faraday, which has the consequence that the inactive conductor within a two-pole air-core coil is very large relative to the active conductor, so that the copper losses within an air-core coil are very large.
This poor utilization in regard to quality and quantity of copper within an air-core coil of the existing machines greatly restricts the output and the degree of effectiveness and, depending on the application, has a number of further problems and disadvantages as a consequence.

These are increased ohmic and inductive resistance and increased coil mass. This leads to heat problems, to large machine volumes, to an increased electrical time constant and starting time constant, and thereby leads to a lower dynamic ratio for motors.
The increased starting time constant results in a slower start, which is disadvantageous both for motors and for generators, e.g. for small wind energy plants.

If one reduces the copper losses within an air-core coil through smaller coil and pole widths, this leads to multipoled machines of lower pole strength, increased eddy current losses within the winding, and, in direct current machines, to increased commutation expense, both in mechanically and electronically commutated machines.
Due to the poor conductor utilization, a large amount of magnetic material must be used in order to achieve a desired output, so that the expense for magnets is very large relative to the output.
In addition, the machine masses and the machine dimensions in the diameter, axially, or in the extension transverse to the direction of movement increase, which is disadvantageous for many utilizations, especially in vehicles and aircraft and in space travel. The increased

waste heat results in a limitation of the output of the machines. Overall, the losses restrict the degree of effectiveness of the machines, which has a particularly disadvantageous effect in uses such as motors for battery operation (e.g. drives in vehicles such as fork lifts, electric cars, and electric boats) and as generators for storage in a battery (e.g. lighting dynamos in vehicles, small wind generators).

The object of the invention is therefore to make a compact, highly effective electrical machine which also offers the advantages of the existing machines and, in addition, provides the possibility of realizing the ideal conditions of Faraday to a much greater degree than the known machines. This means increasing the conductor utilization within a two-pole air-core coil in quality and quantity in a very restricted space and thereby achieving practical, compact machine dimensions. To express it another way, the ratio of active to inactive conductor within a two-pole air-core coil is to be increased in a very restricted space, so that more conductor within an air-core coil is actively in the field, more conductor lies orthogonally to the field, and more conductor within the field has the possibility of lying orthogonally to the direction of movement in a restricted space (depending on the winding specification). In addition, in rotating machines the axial approach of the air-core coil is to be advantageously used, in that it has the overall effect of increasing the active portion of conductor within an air-core coil, and the utilization of the high peripheral speeds is to be connected with the advantages of axial approach, and, overall, greater flexibility of the machine design in a wide spectrum of output classes and areas of application is to be achieved and the previously mentioned problems and disadvantages of the known machines are to be solved.

The object is to be achieved by an electrical machine with the characteristics of patent claim 1 or 2.
The electrical machine according to the invention has an air gap or an air gap consisting of several air gap sections, which is essentially delimited by a field device, which consists of at least one or more first and second bodies positioned neighboring one another and lying opposite to one another in the air gap, with at least one of the facing sides having magnetic poles magnetized orthogonally to the air gap, extending essentially over the entire air gap, either as an entire pole or divided into partial poles, alternating in the direction of movement, and having their fields running in essentially a straight line, within the pole surface region of each pole, from one boundary surface of the air gap to the opposite boundary surface, which either also has magnetic poles and/or consists at least predominantly of return path material. Furthermore, the electrical machine has at least one two-pole air-core coil or a winding with two-pole air-core coils, which has no contact to return path material, is in approximately the center of the air gap in section transverse to the direction of movement, extends in the air gap at a uniform distance from the first and second body, and moves relative to the field device, and each coil side of the at least one air-core coil thereby traverses the direction of movement, and is connected, at the outer edge of the air gap, with another coil side, directly or via inactive conductor, into at least one air-core coil. In the achievement of the object, the air gap consists, in section transverse to the movement of direction, of at least two neighboring air gap sections, each two of which lie neighboring one another and, with their air gap boundary surfaces which belong to the first body, abut one another at the joint edges thus arising. Each coil side of the at least one air-core coil runs through all air gap sections of the air gap, while changing its geometric shape at each of these edges, and each coil side thereby completes a bend

or fold around the first body, and each coil side essentially runs in the air gap. Alternatively, one can also say here that each coil side is bent or folded at the edge during its course through the air gap, and each coil side essentially runs in the air gap. Still another alternative here is that the air-core coil changes its geometrical continuum at the edge at most two times and each coil side essentially runs in the air gap, with a geometrical continuum being a row of points connected with one another which results in a geometrical form (e.g. straight line, circle).

In another achievement of the object, the air gap consists, in section transverse to the direction of movement, of at least one curved air gap section in which each coil side of the at least one air-core coil essentially extends at least in the full length of the curve and runs through the air gap sections of the air gap and essentially in the air gap.

Through the course of the air gap and the direction of the coil, in section transverse to the direction of movement, of the type described, a space-saving alteration of direction of the air gap and the air-core coils is achieved for the machine in which the coil sides essentially lie in the air gap, whereby the proportion of active coil to the coil width and/or to the inactive conductor within an air-core coil is significantly improved, and thus within the air-core coil a very large amount of conductor is highly effective for energy conversion within a very restricted space, so that the magnetic and conductor material is better used. The invention also contains entirely new machine forms.

This type of bending or folding makes possible an advantageous axial approach of the coil sides in accordance with the ideal conditions of Faraday.

Due to the invention, the spectrum of applications of the electrical machines of the generic portion of the first claim is greatly enlarged and, in addition, new ranges of

output are accessible. Furthermore, in principle, this makes possible the solution of all problems of the description of the object.

The most important further developments of the electrical machine discovered in the main claim and in the secondary claim are described in the sub-claims 3 to 37, as they are in a more detailed way in the following:

In the observation of the course of the air gap, the view in section transverse to the direction of movement is always meant in the following.

The concept of field device refers to all parts of the electrical machine which serve for generation, storage, conduction, and delimitation of the magnetic field within the machine, with these being the first and second body delimiting the air gap, the body delimiting the air gap in the folded region of the air-core coil, the magnetic poles applied to one side of the conductor in the folded region, which do not have an air gap delimitation directly opposite, and connecting bodies between the first and second body.
In addition to the preferred possibility of closing the magnetic circle via a return path of the first and second body between neighboring magnetic poles, there is also the possibility of closing the magnetic circle via a connecting body predominantly made of return path material between the pole regions of the first and second body lying opposite in the air gap, with the axle or shaft preferably considered as the connecting body in, for example, rotating machines. This possibility is to be considered if neighboring magnetic poles of a first or second body are separated from one another and, at least in the region of the pole, are designed to be magnetically isolated from one another. This is the case if slots which serve for conduction of coolant for cooling of the winding are inserted between the poles.

For practical purposes, the slots are slanted in the direction of movement so that they simultaneously transport the coolant as propellers.

Ferromagnetic material is preferred as the return path material for manufacturing and cost reasons. A further development is that the at least one curved air gap section is curved circularly. Circularly curved air gap sections offer a very harmonic and effective field distribution.
In a further development of this, the first body is, in section transverse to the direction of movement, a circle or a graduated circle which is preferably a return path and the second body essentially surrounds the first body concentrically at a uniform distance, with the second body having a continuous slot in the direction of movement for leading through the coil holder. The air-core coil is circularly curved around the first body. This further development has the advantage of a uniform field distribution over the entire air gap if the magnetic poles, which are preferably part of the second body, are radially magnetized.

In another further development, the at least one curved air gap section is bent asymmetrically, preferably in the shape of an ellipse. This shape also offers a very harmonic and continuous field distribution, together with an advantageous usage of space, for the air gap and/or this air gap section.
If the elliptical air gap includes a main apex and two secondary apexes, this results in a favorable drum shape for a rotating machine, in which a large amount of conductor of a coil side lies in the peripheral region and, simultaneously, the favorable axle approach is achieved by the conductor in the region of both secondary apexes.
If the elliptical air gap in the ellipse shape is laid out as flat, with a secondary apex and two main apexes, a greatly space-saving machine form results in which, for

example, in rotating machines, the first body is, on one hand, axially narrow due to the disk shape and, on the other hand, the energy-rich peripheral region of the air-core coil is used in a very harmonic way and the axle approach on both sides of the first body is thus advantageously used.

A further development is to have essentially the entire air-core coil inside the air gap.
The winding heads are thus also partially used, so that the copper utilization of the air-core coil improves.

In a further development, the air-core coil, in section transverse to the direction of movement, is bent or folded around an edge of the first body formed by the intersection of two boundary surfaces of two straight air gap sections lying at an angle of less than 180° to one another and each coil side runs at least in the air gap sections on both sides of the edge. This has the advantage that the coil sides take up less space transverse to the direction of movement, which results in a more compact machine, and the folded region of the air-core coil is very short, with the essential part of a coil side lying within the field.

A further development is that at least one curved air gap section abuts with another straight neighboring air gap section at the boundary surface belonging to the first body, forming an edge. In this way, a large portion of conductor of each coil side lies in the air gap, even in the transition from a curved air gap section into the neighboring straight air gap section, and further advantageous embodiments are made possible through the design variants.
A further development of the two preceding further developments is that the edge of two abutting boundary surfaces which belong to the first body and to two neighboring air gap sections is rounded off in section

transverse to the direction of movement. This promotes a uniform field distribution and prevents, for example, the occurrence of saturation in this type of return path region.

In a another further development, neighboring abutting air gap sections transition directly and without a gap into one another, so that both boundary surfaces of the air gap in this region are continuous. A maximal penetration of each coil side by the magnetic field in the region of the edge is thus achieved.
If a circular air gap section neighbors a straight air gap section in this way, one thereby achieves favorable, space-saving, and easily manufacturable shapes for the body of the field device.
These and similar favorable geometric shapes are achieved in the further development described in claim 10. Another advantageous variant should be mentioned here, in which a straight air gap section transitions at one or both of its ends into a curved air gap section.
In all of these embodiments, disks or cylinders can advantageously be used as a manufacturing basis, with these shapes also able to be easily assembled.

A particularly economical and easy to manufacture basic further development is described in claim 11, in which the bent and folded portions of the conductor of each coil side are very short, due to the very narrow, slot-shaped first body.
The edge of the slot-shaped body is preferably implemented as rounded off in the folded region, so that a semicircular edge is formed in section transverse to the direction of movement. This has the advantage of a uniform field distribution in the return path, so that saturation does not occur and the field of the magnetic poles, which are preferably also continued in the folded region of the coil

sides, also penetrates the folded region completely or partially, and is absorbed unweakened by the return path.

A further development is that the air gap, in section transverse to the direction of movement, consists of several abutting air gap sections which are straight or curved, through which each coil side runs, and which thereby complete at least one left and one right bend.
This has the advantage that the coil side is very long in a narrow space, and due to this the proportion of active conductor to inactive conductor of the air-core coil is very large.
A further development of this is that three straight air gap sections, in section transverse to the direction of movement, run parallel to one another and each coil side runs through all three air gap sections, in that it completes a left bend and a right bend when it runs from one section into the neighboring one. This method of folding the coil sides is very space-saving and effective.
Another further development of this is that three straight air gap sections, in section transverse to the direction of movement, neighbor one another, and each coil side runs through them in sequence, with two air gap sections lying parallel to one another and the third air gap section assuming an angle of 90° to them. For rotating motions, this has the advantage that a large part of the conductor lies in the high-speed peripheral region and simultaneously a winding head in the region near the axle is very short. The bell shape hereby has mechanical and manufacturing advantages.

A further development is that, in the folded region of the air-core coil, magnetic poles are affixed on one side whose field does not run in essentially a straight line from the pole surface to the opposite boundary surface in the air gap. This utilization of the folded region of the coil side

is also advantageous, particularly when it lies in the peripheral region of a rotating machine.
Another further development in regard to this is that the folded or bent conductor of the coil side in the folded region is also penetrated by the field, which essentially runs in a straight line. This is advantageous because one thereby achieves the maximum energy conversion, depending on the quality of the field penetration of the conductor.

A further development is that, in section transverse to the direction of movement, at least two neighboring air gap sections of the air gap have, in their boundary surfaces belonging to the first body and abutting one another, magnetic partial poles which, outward over the joint edge, form a joint, continuous pole which is magnetized orthogonally to its air gap boundary surface. This has the advantage that a folded region of the coil sides in the region of the edge of the abutting boundary surfaces is also penetrated by the field in an easily producible way and the magnetic poles of the first body have a larger area and are thereby higher power.

A space-saving and easily producible embodiment of the preceding further development is that, in section transverse to the direction of movement, the at least three air gap sections have magnetic poles in the boundary surfaces of the first body, which are each connected via edges into one magnetic pole, which thus extends over at least the three air gap sections, is magnetized orthogonally to its air gap boundary surface, and is preferably affixed, in section transverse to the direction of movement, around a slot-shaped return path body which forms the core of the first body.

An advantageous embodiment is indicated in patent claim 17. The further development according to patent claim 17 allows flexible machine design in which the machine dimensions and

the size of the poles used can be tailored to the requirements.

An advantageous embodiment is indicated in patent claim 18. The further development according to patent claim 18 allows a compact machine design and the use of large, easily producible high-power poles, which do not belong to the first body, in the connecting air gap sections, and is a basic variant for the embodiment for many further developments.

A further development is that, in section transverse to the direction of movement, the second body is wrapped at least partially around the folded region or a curved conductor region of the air-core coil, following the course of the coil at a uniform distance, and thereby also forms a field device delimiting the air gap in this region. This allows an optimum penetration of the conductor with magnetic field, with, if the second body has magnetic poles, the pole surfaces enlarged around the enclosed region, so that the machine is also significantly higher power overall.

Another further development is that, in section transverse to the direction of movement, at least one second body is bent or folded around the air-core coil in the edge region of the first body, and is connected with a return path flat band, which delimits the air-core coil on one side at least in this coil region, at the outer edge which runs in the direction of movement.
In one embodiment of this, the return path flat band carries magnetic poles on the side toward the air gap, which are preferably magnetized in the direction of the edge or the return path of the first body. This further development has the advantage that the coil region in the region of the edge of the first body is also used in an economical and easily producible way and, in addition, in another embodiment, the return path flat band also borders

an adjoining further air gap section on one side, which has an application in connection with claim 18, e.g. in Fig. 4.

A further development is that several machines border one another, are securely connected to one another, and thereby use a joint second body of the field device, whereby, in section transverse to the direction of movement, in an embodiment with a jointly used return path, a total of one return path is saved, and, in another embodiment, the joint second body is a permanent magnetic body, with each of the bordering machines using one of the two poles, which saves a total of one magnetic pole and one return path.

As a rule, the first and second body are securely connected to one another and move uniformly with one another, with one exception, in which they are only magnetically coupled, so that irregularities can sometimes occur. This is an advantageous further development in, for example, drum-shaped first and second bodies.

A further development is that the movement runs linearly.

A further development is that the movement is rotational relative to an axle or shaft.

Further developments are that the invention operates as a synchronous machine with rotary current, or with alternating current, or with mechanically or electronically commutated direct current.

In a further development, the winding made of air-core coils is implemented as a traveling field winding.

Further developments are that the magnetic poles of the energizing field are permanently magnetic in one distinctive form and are electromagnetic in another form.

The electrical machine according to the invention transforms electrical energy into mechanical energy (motor) and/or mechanical energy into electrical energy (generator).

A further development works as a coil rotor, in another further development, the field device is the rotor.

An embodiment is indicated in patent claim 23. The further development of patent claim 23 allows a support of the air-core coil which provides it with stability in the air gap, but is also journaled in such a way that as much of the conductor of the coil sides as possible is ideally penetrated by the field.

Further embodiments are indicated in patent claim 24. The further development in patent claim 24 allows the coil sides to lie completely in the air gap and the coil support to be affixed in an area of the conductor of the air-core coil inactive for energy conversion.
Further embodiments are indicated in patent claim 25. The further developments in patent claim 25 allow the use of the highly effective coil utilization for various applications.

A further development is that, in rotating machines which have air gap sections approaching the axle or shaft, the air-core coil, viewed axially, generally runs in a V-shape. Corresponding to this generally V-shaped course and depending on the winding scheme, the magnetic poles in this region, seen axially, are also segmented, run to a point in the region nearest the axle, and are thereby implemented at intervals from one another or segmented and closely packed. This further development allows a reduction of the inactive conductor or winding heads.

A further development is that the coil sides run essentially orthogonally to the direction of movement, because this allows the maximum conversion of energy. For rotating machines, this means that the axle or shaft has approaching air gap sections and folded regions of the air-core coils which do not lie orthogonally to the axle, and the coil sides, which are the legs of the V, essentially run in a radial projection. If the air gap section runs orthogonally to the axle, the coil sides in this region run radially. In the peripheral region, the coil sides preferably run axially.

A further development is that, in addition to the ideal orthogonal course of the coil sides, the invention also comprises slanted, bent, or preferably involute courses of the coil sides to the direction of movement, which are used in rotating mechanically commutated motors, above all with none or only one air gap section approaching the axle, and this invention means a significant improvement of the copper utilization for these winding schemes as well. However, it is advantageous for the coil sides to have in their essential parts an angle of not less than 30° to the direction of movement, because otherwise the active portion of the conductor is too small. For most further developments, winding schemes which have an essentially orthogonal course of the coil sides to the direction of movement are advantageous.

A further development is that the generally V-shaped coil sections are part of a two-layered direct current winding whose coil sides run radially in the conductor region far from the axle and preferably run involute or slanted to the direction of movement in the conductor region close to the axle, with the coil legs of the V of an air-core coil belonging to different layers. On one hand, this has the advantage that a large number of closely packed coil sides use the air gap area well, and the air gap also contains

the conductor regions closest to the axle, whose active portion can thus also be used. This type of winding is a highly effective positioning motor, e.g. when it is connected with the shaft.

In a further development, the generally, when viewed axially, V-shaped coil parts of the at least one air-core coil are, in an air gap section approaching the axle or in projection, congruent with the V-shaped coil parts of an opposing air gap section of the same closed air-core coil. This type of symmetrical design simplifies production and causes a balanced voltage and power distribution in the air-core coil.

A further development is that the coil sides are connected with one another according to the principle of wave winding and thereby include n = 3+2m poles, with m being a whole number (m = 0,1,2,3...) and the winding only enclosing a part of the first body in the direction of movement. This layout is advantageous above all in rotating machines, because the partial windings can be produced and assembled more easily, with at least two such partial windings, assembled around the first body, providing a whole winding.

A further development is that the area of the air-core coil in the air gap or in the air gap section approximately corresponds to the area of the magnetic pole lying opposite to it. This allows maximum energy conversion in, for example, operation as a generator.

In a further development, the coil sections, which are generally V-shaped when viewed axially, are distributed close to one another around the periphery of the first body, with neighboring air-core coils belonging to different winding phases and/or having a different winding direction. The entire air gap area is thereby

advantageously covered with air-core coils and magnetic poles.

In a further development of this, the air-core coils lying next one another belong to an electronic motor in which six closed air-core coils are interconnected into three phases, and in each air gap section, eight poles lie opposite to the air-core coil on at least one side and electronic sensors are inserted in the coil region to determine the rotor position for electronic control. The motor is preferably implemented with two coil layers which are twisted relative to one another in the direction of movement. This is a highly effective, current-saving drive motor with very low wow and flutter for, e.g., cassette recorders, record players, or disk drives.

In another further development, the coil parts, which are generally V-shaped viewed axially, of at least one air gap section approaching the axle are positioned overlapping one another, with the region near the axle preferably implemented as multilayered and the field region preferably implemented as single or double layered. The air gap area is thus covered by several coil sides, without increasing the air gap width or the short winding head conductor or inactive conductor lying in the energy-weak region near the axle.

In a further development of this, the closed air-core coils, with several windings within a two-layered direct current winding over the periphery of the first body, are twisted, distributed, and preferably interconnected via a commutator by one commutator pitch after each turn. In the axial region, the winding overlaps in multiple layers, so that this coil region is left out of the field region. This is a highly effective positioning, servo, and stepping motor, which achieves the highest accelerations at the highest torques and the lowest wow and flutter as a coil rotor.

A further development is that, in the air gap section approaching the axle or shaft, viewed axially, at least one air-core coil is implemented as a diametral winding, with it being advantageous to apply at least one further diametral winding, e.g. twisted 90°, to it and to overlap them near the axle. This is a particularly economically producible motor with easily producible air-core coils which, with comparatively typical diametral windings, has a high conductor utilization, a high efficiency, and a high torque, and which can also be used with space-saving disk design for very small drives, such as for clocks.

A further development is that the at least one air-core coil is connected with an axle or shaft, e.g. in an implementation as a coil rotor.
In an embodiment of this, the axle is implemented as a hollow axle, and is advantageous in, e.g., a coil support implementation as in a bicycle hub dynamo.

A further development is that the second body of an air gap section approaching the axle is, viewed axially, implemented as a ring whose inner edge is at a distance from the axle or shaft to lead through the coil support. The energy-rich peripheral region of the air-core coil can thus also be used, with the energy-poor region near the axle, having the winding head or the conductor lying in the direction of movement, serving for coil support.

A further development is that the at least one air-core coil is implemented as a direct current winding which is commutated via a collector or directly on the winding, so that the advantages of high coil utilization and compact design also expands the field of use of these machines with this type of winding.

A further development is that magnetic poles are affixed on both sides in the air gap or at least in one air gap

section. This has the advantage of a stronger field in the air gap or in the air gap section.

An advantageous embodiment is indicated in patent claim 28. The further development according to patent claim 28 has the advantage that nearly the entire lengths of the coil sides lie in the air gap, because the folded conductors are very short. Further advantages are a large torque with a relatively small diameter and a very narrow axial design.

In a further development of this, the field device comprises three circular disks, of which the first disk is a thin return path disk of uniform thickness, and the magnetic poles of the second body extend radially and are axially magnetized. The three disks are securely connected with the axle or shaft. The shaft or axle is rotatably journaled in a housing which surrounds the field device, with at least one air-core coil connected in its peripheral region via a support with the housing. This further development has the advantage of a particularly short axial length and, in addition, is simple and economical to produce.

In an embodiment of the two preceding further developments, the conductor in the peripheral region is also at least partially surrounded along its length, in section transverse to the direction of movement, by a field device, and thereby penetrated by the field. Various further developments of this are described in the patent claims 15, 19, and 21, and illustrated in the figures 3/9. This embodiment results in a further increase of the coil utilization and thereby a further improvement of the machine properties.

An advantageous further development is indicated in patent claim 29. In a further development according to patent claim 29, as it is illustrated in, for example, Fig. 14, the advantages are an increased performance and a greater

torque in comparison to the machine with a simple return path disk as the first body.

A further development of this, as illustrated in Fig. 8, is that the field device, which at least partially encloses the conductor in the folded region and peripheral region of the air-core coil along its length, is designed in such a way that the magnetic poles on the first disk-shaped body are wrapped around the outer edge of the internal slot-shaped return path body of the first body and thereby are preferably correspondingly magnetized to the bending radius of the air-core coil in the folded region. The expenditure for magnets necessary to penetrate the peripheral region of the air-core coil is hereby low, which additionally advantageously leads to large-area poles of the first body, which extend over both air gap sections, and the effectiveness is thus very high.

Another further development of this, as illustrated in Fig. 4, is that the field device, which at least partially encloses the conductor in the folded region and peripheral region of the air-core coil along its length, is connected in this region with the outer edge, lying in the direction of movement, of the slot-shaped return path body of the first body with a narrow return path flat band lying in the direction of movement, which is preferably flat or semicircular in section transverse to the direction of movement and is a ring-shaped body when viewed axially, whose width approximately corresponds to the width of the first body in the direction of magnetization, with the return path flat band affixed at a distance from the faces of the magnetic poles of the first body and further magnetic poles affixed in the air gap in the part of the field layout lying radially opposite to the return path flat band.

In an embodiment of this, the first disk-shaped body has magnetic poles on both faces, with the return path flat band connected approximately in the center with the return path body of the first body.

In another embodiment of this, the first disk-shaped body has magnetic poles on one side, with the return path band connected at its outer edges with the return path body of the first body.
The advantage of the further development and its embodiments is that the machine is relatively narrow, with, however, the conductor region in the peripheral region penetrated by the field so long and effective that the machine has a large output and a large torque. The magnetic poles in the peripheral region are relatively large, because they lie outside the air-core coil, which also increases the output.

A further development of this is that at least a second disk-shaped body uniformly follows the coil course in the folded region at a distance, as in, e.g., Figs. 8/9. This has the advantage of large pole areas, shortening of the air gap, uniform field distribution, and straight field lines.

A further development is that at least one second disk-shaped body is connected with a return path flat band, which, for rotating machines, is a return path ring when viewed axially, externally bordering the folded region. This is a simple and economical solution for the design of the return path in the folded and peripheral region of the air-core coil, preferably for opposing first bodies whose poles are wrapped around the outer edges.

A further development of this is that the return path flat band has magnetic poles on the side toward the air gap which extend transverse to the direction of movement, alternate in the direction of movement, and preferably are magnetized in the direction of the folded edge of the first disk-shaped body, with the folded edge of the first body forming a return path, as illustrated in figures 3/4/5, or having magnetic poles wrapped around it. These magnetic

poles of the return path flat band are advantageously easy to produce.

In a further development, the disk-shaped bodies are three circular disks which are essentially uniformly fixed in the air gap region, and by means of which the second bodies in the peripheral region, in section transverse to the direction of movement, are connected with another, preferably by a return path flat band, which is a ring-shaped body when viewed axially and has magnetic poles on its inside, and the first body is connected with a second body in the axle region, preferably by a flat band which is a ring-shaped body when viewed axially, with the air gap winding preferably implemented as a direct current winding which is either commutated via a collector or directly on the winding, and the partial coil of an air gap section connected with the shaft, or the air gap winding connected with a partial coil with a hollow axle for passing through the conductor, with the axle or shaft preferably led through on one side out of the air gap region, whereby the air-core coils and the axle or shaft can be supported axially opposite to one another.

This further development offers the advantage that the coil support is applied in the winding head region and each coil side can thereby be completely penetrated by the field. This can be advantageously used as a mechanically commutated coil rotor or magnetic rotor with a hollow axle, e.g. as a bicycle hub dynamo. In a further development of this, the peripheral region is partially used as described earlier.

In a further development of this, the air gap winding is not connected with the axle or shaft, but rather its coil support in the region near the axle is led through axially out of the air gap region between the shaft or axle and a second disk-shaped body, which is a disk ring, as illustrated in Fig. 5. In one embodiment, the axle or shaft is led out of the air gap region on one side, as

illustrated in Fig. 18. This has the advantage that the axle or shaft is led out on one side from the disk region, so that the axially opposite region of the axle or shaft serves for leading the coil support out of the air gap region, which is affixed to the inactive conductor or winding heads near the axle, so that the air-core coil can be optimally used and this is in connection with an economical and easily producible field assembly.

In another further development, as illustrated in figs. 6/7, two machines, each with three disk-shaped bodies, are coaxially assembled into one machine at a distance from one another for a total of five disk-shaped bodies on a joint axle or shaft, with the central disk-shaped body serving both windings of the original machines. The advantage of this combination is that one saves either one return path or one tier of magnetic poles and one return path, depending on how the original machines are designed in regard to pole distribution.

The particular advantages of the further development of the invention with disk-shaped first and second bodies lie in the flexibility in machine design, low mass, low moment of inertia, small axial length with relatively small diameter, extraordinarily high efficiency, low electrical and starting time constants, large torque, linear characteristics, low ohmic resistance, good self-cooling, and high electromagnetic compatibility.
The machine is thus particularly suitable as a server motor, stepping motor, positioning motor, drive motor for vehicles, particularly battery-operated or hybrid drives, and as a light dynamo for vehicles, e.g. in cars or bicycle hubs, and as a generator, e.g. for small wind power plants.

Another advantageous embodiment is indicated in patent claim 30. The further development in patent claim 30 allows very long coil sides in the air gap with a relatively short

axial length of the machine, with the coil sides predominantly lying in the energy-rich peripheral region, but the axial approach, with its shortening effect on the winding heads and inactive conductor, also used. In addition, a uniform field distribution is achieved in curved air gap courses.

An advantageous embodiment is indicated in patent claim 32. The further development in patent claim 32 allows maximum utilization of the high peripheral speeds, depending on the overall axial length, while simultaneously shortening the inactive conductor near the axle.

In a further development of the two preceding further developments, the circular cylinders are securely attached to the shaft or axle and the second drum-shaped body has a continuous slot along its shell surface for leading through the coil support, with the slot preferably dividing the second body approximately in its center in the axial direction or running in a folded region of the air-core coil. This has the advantage of stabilizing the air-core coil in the air gap, so that long coil sides can be used. For bell-shaped windings, this coil support is preferably affixed in the folded region, because it thus stabilizes both coil parts well on both sides of the folded region. This support, in which the external second hollow cylinder is interrupted along the length of the air gap by the slot, is preferably used for inner poles, because in this case, only there can large continuous pole surfaces of one polarity be realized.

In another further development of the three preceding developments, the first and second drum-shaped bodies are journaled on the axle or shaft, with the first body, in section transverse to the direction of movement, surrounded by the at least one air-core coil, which is connected on both sides in its regions near the axle with the axle or

shaft, and with the first and second bodies not securely, but rather magnetically, connected with one another.
This offers the advantage of complete penetration of the air-core coil with magnetic field and a support in both inactive conductor regions or winding heads, so that long axial coil sides and therefore outputs can be achieved. For use as a coil rotor, the coil is hereby connected with the shaft, with slip contacts preferably supported near the axle by the second body connected directly with the air-core coil or with a collector.
For use as a magnetic rotor, as illustrated in Figs. 24/25, the coil conductor is led outward through a hollow axle.

In another further development, the air gap sections on the face, which preferably run orthogonal to the axle, of the preceding three further developments and their embodiment, as indicated in patent claim 33, are replaced, in section transverse to the direction of movement, by slanted and/or curved, particularly circular, air gap sections. These further developments offer uniform field distribution and location of the coil sides either completely in the air gap, in the region of the edge of the first body, or an only briefly bent conductor in the edge region, which runs outside the air gap.

An advantageous embodiment is indicated in patent claim 31. The further development in patent claim 31 allows economical, easy to assemble implementation.
In a further development of this, the first drum-shaped body has the shape of a full or hollow circular cylinder and the second drum-shaped body has the shape of a hollow circular cylinder, with the first drum-shaped body only having a face delimiting the air gap on one side, and the at least one air-core coil attached at its region near the axle with the shaft, with the circular cylinders securely attached to one another at their peripheral regions on their faces free from the air gap, and the winding provided

with a mechanical commutation. This is a highly effective, easy to assemble, bell-shaped coil rotor.
In an embodiment of this, the shaft is only implemented on one side from the air gap section on the face, as illustrated in Figs. 22/23, which has the advantage of applying the slip contacts to the axle axially opposite in the region of low speed and wear.

In another further development, the air gap section on the face, which preferably runs orthogonally to the axle, of the preceding further development, as indicated in patent claim 33, is replaced by a course of the air gap section which, in section transverse to the direction of movement, is slanted and/or curved, particularly circular. These further developments offer a uniform field distribution and location of the coil sides either completely in the air gap, in the region of the edge of the first body, or an only briefly bent conductor in the edge region, which runs outside the air gap.

In a further development, the magnetic poles belong to the shell surface and face of the first drum-shaped body and are implemented as rounded off in the edge region and correspondingly magnetize the fold radius of the conductor in the edge region.
In another further development of the preceding drum-shaped further developments, the magnetic poles in the shell region belong to the at least one first drum-shaped body and, in the face region, to the second drum-shaped body, with a return path, lying opposite to the magnetic poles in the face region, which belongs to the first body and extends over the complete diameter of the first body and to which the face of the magnetic pole on the shell side of the first body is affixed at a distance along the axle.
In another further development, the magnetic poles on the shell side belong to the second body and the magnetic poles on the face belong to the first body.

These mixed forms of inner and outer poles in the air gap have advantages in tailoring to the necessary machine dimensions, output, and costs, and offer almost complete penetration of the air-core coil with magnetic field.

An advantageous embodiment is indicated in patent claim 34. The further development in patent claim 34 allows a short axial length of the machine with, in the region of high speeds, long coil sides, which are preferably supported in the winding head or folded region.
A further development of this, illustrated in Figs. 27/28, is that three cylindrical bodies, in section transverse to the direction of movement, delimit two air gap sections through which each coil side of the at least one air-core coil runs and the magnetic poles belong to the respective second hollow cylindrical body and the first hollow cylindrical body is a return path. The advantage here is the simple design of the machine and the short folded or bent region of the coil sides in the region of the edge of the first body.
In another further development of this, as, for example, in Figs. 31/32, the magnetic poles belong to the second hollow cylindrical body near the axle and to the first hollow cylindrical body, with each of these bordering the air gap section on the inside and also the faces of two cylinders bordering an air gap section on one side through which each coil side runs.
This has the advantage that little magnet mass lies in the peripheral region because permanent magnets are used.

A further development is that, as illustrated in Figs. 29/30, four cylindrical bodies, of which at least three are hollow cylinders, in section transverse to the direction of movement, delimit three air-gap sections between their shell sides, through which each coil side of the at least one air-core coil runs and thereby contains a bend and/or fold with a left and right curve. This has the

advantage of long coil sides and thereby better copper utilization with relatively short axial length of the machine.

In a further development, the coil sides run axially in the hollow cylindrical air gap section. This is the conductor utilization in this region which is qualitatively highest.

In another further development, the coil sides run in the hollow cylindrical air gap at a slant to the direction of movement and essentially in a zigzag shape, according to known winding schemes for mechanically commutated direct current machines, through the air gap sections, in order to make a new staggered convolution after every convolution around the periphery, etc. The magnetic poles are thereby rhomboidal, with their points lying toward one another around the periphery, preferably distributed in sections on the air gap sections. This further development has the advantage that the air-core coil has a high mechanical strength, if it is designed as a self-supporting winding, which also includes simple production. This is particularly advantageous for air-core coils which extend between hollow cylindrical first and second bodies in air gap sections only on the shell side or also in combination with an air gap section approaching the axle or also in a drum-shaped air gap section bent in section transverse to the direction of movement.

In another further development, the field device, in the shape of three cylindrical bodies and at least one disk-shaped body axially separated from them, are located coaxially and separated from one another in the radial direction on the axle or shaft, forming the field device and with at least the two external cylindrical bodies being hollow cylinders, with each of the first cylindrical body and the second cylindrical body, in section transverse to the direction of movement, delimiting a narrow rectangular

air gap section whose long sides run parallel to the axle and parallel to one another, and at least one of the shell sides of the first and second cylindrical bodies facing one another provided with axially extending magnetic poles, with a radial direction of magnetization, which alternate around the periphery, and a face of the cylindrical body, which is advantageously the face of the central hollow cylindrical body, near the axle and the disk-shaped body lying axially displaced from it delimiting, in section transverse to the direction of movement, a further narrow rectangular air gap section approaching the axle, and at least one of the faces of the cylindrical body near the axle and the disk-shaped body facing one another containing magnetic poles which extend radially and are axially magnetized, with each coil side of the at least one air-core coil running through all three air gap sections, and, in section transverse to the direction of movement, thereby completing a bend and/or fold with one left bend and one right bend, and the field device rotatable relative to the at least one air-core coil.

The advantage here is that a majority of the coil side lies in the energy-rich peripheral region and a winding head or inactive coil region near the axle is very short. In addition, the machine is very short axially and has high output and high torque. In a further development of this, further magnetic poles with an axial direction of magnetization are applied to a further disk-shaped return path in the folded region of the air-core coil, with this disk-shaped field device preferably forming the face of the outer hollow cylinder, and lying coaxially to the shaft or axle with the remaining field device, and securely attached with the remaining field device.

An advantageous embodiment is indicated in patent claim 35. The further development in patent claim 35 allows a linear machine with a winding having two-pole air-core coils with

good copper utilization within each air-core coil and a space-saving compact design.

An advantageous embodiment is indicated in patent claim 36. The further development in patent claim 36 allows a short bent or folded region of the coil sides, so that very little conductor in the edge region of the first body lies outside the air gap and the machine is very narrow in the direction of magnetization of the magnetic poles.

A further development of this is that the field device consists of three long, plate-shaped bodies which are connected at both of their long edges via a connection body, which is preferably a flat band, and the air-core coils of the winding preferably run congruently in the parallel air gap sections, with the coil sides preferably lying orthogonal to the long sides. This is a simple, particularly compact, easy to assemble machine, with the air-core coils supported in the bend or folded conductor region, preferably orthogonal to the air gap surface, so that the folded region can preferably also be extensively delimited by a field device.

Another further development of this is that the field device consists of three long, plate-shaped bodies, with the two second plates connected to one another at one of their two long edges and the first plate securely connected with a second plate at the opposing long edges, each via a connection body which is preferably a return path flat band, and the air-core coils of the winding running congruently in the parallel air gap sections, with the coil sides preferably lying orthogonal to the long side. This further development has the advantage that the bent or folded conductor can also be penetrated by the field and that the coil support is affixed to an inactive conductor region or to the winding head, and the design is also

suitable for field devices which are very long in the direction of movement.

Another further development of this is that the field device consists of three plate-shaped bodies, with the plate-shaped bodies connected with one another on their short sides via a connection body and the air-core coils of the winding in the parallel air gap sections preferably congruent, with the coil sides preferably running orthogonal to the long side. This is a simple achievement of the design suitable for field devices which are short in the direction of movement and offering the possibility of penetrating the air-core coil with field lines in the folded region as well, with additional magnetic poles in this region. The coil support can also alternatively be applied in the inactive conductor region or in the folded region, depending on the application, and the design is easy to assemble.

Another further development of the three preceding further developments is that, in the folded region of the air-core coil, magnetic poles are affixed whose carrier is a magnetic return path flat band which is preferably securely connected with at least one second plate at one of their long sides.
In combination with one of the four preceding further developments, the conductor bent or folded is used in this way in the region of the edge of the first body, which increases the copper utilization.

Another further development as a linear machine is that the at least one air-core coil is bent or folded around a first body which, in section transverse to the direction of movement, is essentially a circle, a triangle, a rectangle, or a square, with each coil side bent around the first body or around one or more edges of the first body, forming each corner of the polygonal cross-section of the first body,

and hereby running at least through one bent or two neighboring straight air gap sections.
The advantages of these further developments are that each coil side is long in a narrow space. In a use with an air-core coil traveling field winding, in which the air-core coils form the long stator and the field device forms a short rotor, such a design brings a magnetic cushion both for support of the rotor and for its lateral stabilization, if it moves freely. In this way, extra coils for lateral stabilization are saved by the coil design.

In the field of air-core coil machines and their classical applications, the electrical machine according to the invention is a great developmental step in the electrical and mechanical field. It is particularly suitable for small to medium outputs.

The machine according to the invention is an outstanding drive motor for vehicles, particularly for battery-operated vehicles (cars, fork lifts, boats, bicycles, wheelchairs). The extraordinarily high efficiency, the low rotational and translational mass, the high starting and braking torque, and the rapid and exact adjustability, combined with compact and simple implementation, all speak for this invention.
Furthermore, the machine according to the invention is ideally used, in the form of the coil rotor, as an outstanding servo and stepping motor, both in linear and rotating designs. The reason for this lies in the low rotor mass, the low inactivity, and the low ohmic resistance.
Because the copper is utilized in an optimal way, this leads, in connection with the linear voltage/speed characteristic, to machines with outstanding adjustability and the highest dynamic ratios.
Also, due to the low wow and flutter, the invention is very suitable as a drive motor in disk drives, video recorders, and tape recorders.

A further area of use is as a generator. The first indication for this use is the linear voltage/speed characteristic, which has the consequence of that the voltage can increase proportionally with the speed largely unlimitedly, which allows a high energy conversion even in high speed ranges, and is of great use for regulated storage in a battery. The high utilization of the winding results in a very high efficiency and, due to the low internal resistance, allows a high power withdrawal. In connection with the compact construction, this allows the invention the utilization of air-core coil generators in new areas of use, such as hub dynamos in bicycles. In this usage, the generator can, due to the extremely low no-load operation losses, always rotate, and can be switched on and off electrically, and is, as a permanent magnet rotor, free from wear and maintenance. The invention is also of great value when used in small wind generators. In addition to the advantages mentioned, the good starting and run-up characteristics should be noted in this connection.

The machine according to the invention is ideally suited for a high output vehicle light dynamo. A powerful light dynamo is needed which takes into consideration the increased performance requirements due to ever more electrical consumers in vehicles, and simultaneously significantly improves efficiency relative to the current claw pole rotors. The low translational and rotational masses are also advantageous in this case.

Embodiments of the invention are described in the following with reference to drawings. These show

Fig. 1 a cross-section through a further development,

Fig. 2 the section along the line I-I in Fig. 1,

Fig. 3 a schematic cross-section through a 2nd further development,

Fig. 4 a schematic cross-section through a 3rd further development,

Fig. 5 a schematic cross-section through a 4th further development,

Fig. 6 a schematic cross-section through a 5th further development,

Fig. 7 a schematic cross-section through a 6th further development,

Fig. 8 a schematic cross-section through a 7th further development,

Fig. 9 a schematic cross-section through an 8th further development,

Fig. 10 a schematic cross-section through a 9th further development,

Fig. 11 a section along the line II-II in Fig. 10,

Fig. 12 a schematic cross-section through a tenth further development,

Fig. 13 a section along the line III-III in Fig. 12,

Fig. 14 a schematic cross-section through an 11th further development,

Fig. 15 a section along a line IV-IV in Fig. 14,

Fig. 16 a top view of a disk with a partial coil lying in front of it in another further development,

Fig. 17 a 12th further development in a section along the line I-I in Fig. 1,

Fig. 18 a schematic cross-section through a 13th further development,

Fig. 19 a section along the line V-V in Fig. 17,

Fig. 20 a schematic cross-section through a 14th further development,

Fig. 21 a top view of a disk ring with an air-core coil according to Fig. 20,

Fig. 22 a schematic cross-section through a 15th further development,

Fig. 23 a section along the line VI-VI in Fig. 22,

Fig. 24 a schematic cross-section through a 16th further development,

Fig. 25 a section along the line VII-VII in Fig. 24 and along the line VIII-VIII in Fig. 26,

Fig. 26 a schematic cross-section through a 17th further development,
Fig. 27 a schematic cross-section through an 18th further development,
Fig. 28 a section along the line IX-IX in Fig. 27,
Fig. 29 a schematic cross-section through a 19th further development,
Fig. 30 a section along the line X-X in Fig. 29,
Fig. 31 a schematic cross-section through a 20th further development,
Fig. 32 a section along the line XI-XI in Fig. 31,
Fig. 33 a schematic cross-section along the line XII-XII to of Fig. 34 through a 21st further development,
Fig. 34 a section along the line XII-XII in Fig. 33,
Fig. 35 a section along the line XIV-XIV in Fig. 34,
Fig. 36 a section along the line XV-XV of Fig. 37 through a 22nd further development,
Fig. 37 a section along the line XVI-XVI of Fig. 36,
Fig. 38 a section along the line XVII-XVII of Fig. 36,
Figs. 39 to 41 enlarged details in the region of the folded edge of the air-core coil.

The same components have the same reference numbers in all figures.

The figures show various further development of the design of the field layout and the air-core coil and/or winding and their relationship to one another, as well as their utilization.

The magnetic poles are, as much as possible, depicted as permanent magnets for the sake of simplicity. For reasons of clarity and saving space, the permanent magnets are implemented as very narrow (in the direction of magnetization), so that the magnets must be up to two to three times as thick depending on which magnetic material, which power class, and which application it is.

In the figures which do not yet relate to a concrete application, but illustrate a general further development, the connection of the air-core coil or the field device to the axle or shaft or the housing can be changed. This also applies for determining which is the rotor and which is the stator and whether it is an axle or shaft and will be determined in detail according to the requirements of the utilization.

The first body is the body which forms at least the boundary surface or the boundary surfaces around which the coil sides of the at least one air-core coil are bent or folded. If the coil sides make a right and a left bend in their course, the assignment of the title for the first and second body is dependent on which bend or fold is considered.

Fig. 1 shows an electrical machine in axial section. A first disk-shaped body 6 forms a narrow return path disk of uniform thickness. A second disk-shaped body 7 consists of two disks which each consist of a magnetic disk backed with a return path disk. The disk-shaped bodies are securely attached to a shaft 1 journaled in 13 and move uniformly relative to the housing 2 and the coil 3 connected with it. The air-core coils 3 are folded at 20 around an edge 10 of the first disk-shaped body 6, with the coil sides running in the respective air gap section 4', 4" between the first and the second disk-shaped body up to near the axle. The air-core coils are radially connected with the housing in the bent region 20. A characteristic here is that the periphery of the second disk-shaped body 7 corresponds to the periphery of the air-core coil, so that the conductor 20 in the folded region 18 of the air-core coil is also partially penetrated by the field.

Fig. 2 shows an electrical machine from Fig. 1 in radial section. Magnetic poles 27 are implemented as permanent

magnets in the shape of segments of a circle, which are alternately distributed lying close to one another around the return path surface and belong to the disk-shaped second body 7. One coil width 14 corresponds here to the pole width 12. The V-shaped air-core coils, whose coil sides run slightly displaced from the radius, are segmented, and are positioned close to one another and opposite to the magnet segments in the air gap.

Fig. 3 shows an electrical machine in axial section. The characteristic of this machine relative to that of Fig. 1 is that the conductor at 20 in the folded region 18 is penetrated by the field to a higher degree than in Fig. 1 due to additional measures. For this purpose, a disk-shaped body 7 is wrapped around the periphery of the air-core coil 3 with a return path ring 5, which is ring-shaped when viewed axially, and the inner surface delimiting the air gap is formed by axially aligned permanent magnetic poles 27. The outer edge 10 of the first disk-shaped body is semicircular in axial section. A coil support 21 is implemented axially and connected through a slot in the second body in a folded region of the coil sides with the peripheral region of the air-core coil 3. This allows a large copper utilization.

Fig. 4 shows an alteration of the electrical machine from Fig. 3 in axial section. The characteristic here is that in the disk-shaped air gap region, the magnetic poles belong to the first disk-shaped body 6, and the peripheral region and part of the folded region of the air-core coil are used simultaneously. In order to allow this, the return path disk of the first disk-shaped body is securely connected at its peripheral region with a return path ring 9, which is narrow when viewed in radial section, whose axial width corresponds to that of the first disk-shaped body and which is centrally connected with the outer edge of the return path core 19 of the first disk-shaped body 6, without

magnetically short-circuiting the faces of its permanent magnets. The peripheral region of this return path ring 9 is rounded off at the outer edges toward the air gap. As in Fig. 3, a field device 5, which is ring-shaped when viewed axially and whose inner surface, which delimits the air gap, is formed by axially aligned permanent magnets, lies opposite to it. A further characteristic here is that magnetic poles delimit both sides of each air gap section in the disk-shaped air gap sections.

Fig. 5 shows an alteration of the electrical machine from Fig. 3 whose first disk-shaped body 6 is a return path disk. The characteristic here is that the second field device 7 completely surrounds the first disk-shaped body 6 with a ring-shaped carrier 5, so that one single closed air gap results, with the surfaces of the external field device delimiting the air gap delimited by permanent magnets 27 both in the disk-shaped part and in the ring-shaped part of the air gap. A further feature here is that the coil support 21 is securely axially connected with the air-core coil and/or winding at a region of the conductor inactive in energy conversion and is led out of the air gap region. An assumption for this is that the one second disk-shaped body is a disk ring 16.

Fig. 6 shows a further development of the electrical machine which is assembled from two machines, each with three disks, on a joint shaft 1 in such a way that two second field devices 7 between the air-core coils are combined into one joint device. The joint second field device is a magnetic disk 23 which is axially magnetized. Due to this combination of the two machines, one saves a total of one magnetic disk and one return path. The two external second disks of the overall machine delimit the air gap sections with permanent magnets which are backed with a return path disk. The coil support 21 is radially affixed in the peripheral region of the air-core coils.

Fig. 7 shows a further development of an electrical machine, which, as in Fig. 8, is assembled from two machines, with, in this case, the joint second field device 7 only having the return path part, on which the magnets 27 of the respective original machines are applied on both sides on the disk surfaces, combined.

Fig. 8 shows an alteration of the electrical machine from Fig. 3, in which the second disk-shaped bodies are bent inward in the peripheral region and follow the coil course at a uniform distance up to the radially affixed coil support. The second disk-shaped bodies 7 are return path disks and the first disk-shaped body 6 is a disk with a disk-shaped return path body 19, slot-shaped in axial section, which carries magnetic poles in the entire region delimiting the air gap, i.e. also in the peripheral region. The magnetic poles are magnetized orthogonally to the air gap boundary surface.

Fig. 9 shows the same disk course as in Fig. 8, however, here the first disk-shaped body 6 consists of a return path disk and the second disk-shaped body 7 consists of a magnetic return path with magnetic poles delimiting the air gap which are magnetized orthogonally to its air gap boundary surface. The air-core coil is supported very stably by a central continuous slot between the second disk-shaped bodies 7.

Fig. 10 shows, in axial section, a further development of an electrical machine with air-core coils 3 which are affixed overlapping in the axle region and in which air gap sections penetrated by the field run in one layer. The second disk-shaped body 7 consists of each of the magnetic poles delimiting the air gap section and a magnetic return path, with the first disk-shaped body being a return path disk.

Fig. 11 shows a further development of the electrical machine according to Fig. 10 in radial section. The distribution of the air-core coils 3 by means of the V-shaped partial coils within an air gap section is visible, with the air-core coils uniformly distributed over the periphery of the first disk-shaped body 6. The permanent magnets 27 of the rear second disk-shaped body 7 are visible in the peripheral region and, furthermore, are indicated with dashed lines, whereby they bypass the winding head region near the axle.

Fig. 12 shows a further development of the electrical machine as a direct current machine with mechanical commutation 25/26 in axial section, in which the air-core coils 3 overlap in two layers in the air gap region and overlap multiple times as winding heads in the axial region bypassed by the field, which is illustrated here in a simplified way by an axial swelling of the winding. The first disk-shaped body 6 is a return path disk and the second disk-shaped body 7 consists of each of the magnetic poles 27 delimiting the air gap section and a magnetic return path. The air-core coils are interconnected on the disk-shaped commutator 25. Slip contacts 26 are also visible.

Fig. 13 shows the further development of the electrical machine according to Fig. 12 in radial section, with the air-core coils uniformly distributed over the periphery of the first disk-shaped body 6 and overlapping in the air gap region as a two-layer winding. The permanent magnets 27 of the rear second disk-shaped body 7 are visible in the peripheral region and are also indicated with dashed lines, whereby they bypass the winding head region near the axle.

Fig. 14 shows a further development of the electrical machine as a direct current machine with mechanical commutation 25/26 in axial section, in which the air gap 4,

in the section transverse to the direction of movement, is formed from two straight air gap sections and one bent air gap section, which transition directly into one another, and the air-core coils 3 extend from the region of a straight air gap section near the axle via the bent air gap section lying in the peripheral region up to the region near the axle of the adjoining straight air gap section. Another further development which is not shown is elliptical in a similar form with a continuous elliptical air gap.

Fig. 15 shows the further development of the electrical machine according to Fig. 14 in radial section, with the air-core coils, visible here only as partial coils, uniformly distributed over the periphery of the first disk-shaped body 6 as individual conductors in a slanted winding, and either directly commutated via brushes 26 on the winding or connected with a commutator 25. The air-core coils run in two layers in the entire air gap, with the coil sides of an air-core coil belonging to different layers. In another further development which is not illustrated here, the conductors in the region run involute or slanted near the axle and radially or radially projected in the remaining region.

Fig. 16 shows an illustration of the principles of a coil guide as a further development for a rotating electrical machine in principle according to Fig. 1 in the radial section of line I-I. In this case, two open air-core coils with several windings are distributed over half of the periphery of the first disk-shaped body and are combined into a partial winding. Two of these partial windings result in the complete winding which fills out the disk circle, with the coil sides distributed uniformly running radially over the periphery.

Fig. 17 shows an alteration of the electrical machine of Fig. 2 in radial section. The characteristic here is that the pole width 12 is smaller than the coil width 14 and electronic sensors 17 are inserted in the winding region. Such machines are used as electronically commutated motors, with the sensors providing information on the rotor position and direction and air-core coils lying opposite interconnected into a phase winding.

Fig. 18 shows a further development of the electrical machine in axial section, with the air-core coil 3 folded as a diametral winding around the first disk-shaped body 6, which is implemented as a return path disk. The axle 24 is only journaled and traced on one side by the first disk-shaped body 6, with the coil support 21 lying opposite the axle 24 and led out of the disk ring 16 in the axle region. The air-core coil only goes past the axle in one air gap region. In another air gap region, it runs directly over the axle or laterally displaced to the diameter. The folded region 18 of the air-core coil is penetrated by the field.

Fig. 19 shows the further development of the electrical machine according to Fig. 17 as a disk machine in radial section. The leading of the axle on one side through the winding is visible here, with the conductors deviating through the axle through hole away from their ideal course. The ideal course of the winding in the nonvisible air gap section is indicated in a dashed form. The magnet system is implemented with two poles per air gap section, which is visible through the magnets 27 of the second disk-shaped body of the rear air gap section.

Fig. 20 and 21 show an implementation with a disk-shaped carrier 8, which ends in a fork shape at its outer periphery in three ring-shaped bodies which are connected, with the two external ones carrying magnets 27 on their inner sides. The disk-shaped carrier 8 sits on a shaft 1,

and the first ring-shaped body is surrounded by the air-core coil 3. High peripheral speeds are used here.

Fig. 22 shows a further development of the electrical machine in axial section. The first hollow cylindrical body 6 consists of a hollow cylindrical return path body on whose shell surface a permanent magnetic body 27 with radial magnetization is applied all around the periphery. A narrow return path disk ring, which is securely connected on the inside with the hollow cylindrical return path body, is applied at a slight distance to the face of the magnetic body. The first body is journaled on its internal diameter on a shaft 1 by two bearings 13 and is coaxially nested in a second hollow cylindrical body 7 and securely attached to it at one face. The first and second bodies delimit an air gap section on the opposite face of the first body and between their shell surfaces. The air gap delimitation on the face is formed by the first body 6 by a return path and by the second body 7 by radially magnetized permanent magnets with a backing return path. The air gap delimitation on the shell side of the second body 7 is implemented as a return path. The air-core coil 3 extends axially via the air gap section on the shell side over the folded region 18 into the air gap section on the face up to near the axle and is connected there with the collector 2, which the slip contacts 26 press against.

Fig. 23 shows an electrical machine from Fig. 22 in radial section. The V-shaped coil sections run slightly displaced from the radius in the face region and are connected with the collector 25 near the axle. The first body 6 is visible as a return path body, as is the second body 7. Furthermore, the coil parts running in the direction of movement in the air gap section on the shell side are visible.

Fig. 24 shows a further development of the electrical machine in axial section. A first hollow cylindrical body 6 consists of a return path body which nests in a second hollow cylindrical body 7, which, between their shell region and the two face regions, delimits an air gap 4 consisting of the air gap regions 4', 4", 4'". The first and second bodies are not connected mechanically, but magnetically, and are coaxially journaled on a hollow axle 24, each by two bearings 13. The air-core coil 3 extends axially into the air gap 4" and is folded at each of the outer edges of the first body at 18 and extends outward from there in the direction of the shaft into the air gap sections 4', 4". The air-core coil is securely attached to the hollow axle 24, with the supply lead of the air-core coil led through the hollow axle. The second hollow cylindrical body 7 consists on the air gap side of permanent magnets 27 which are affixed to a return path body.

Fig. 25 shows an electrical machine from Fig. 24 in radial section. The V-shaped coil sections of the air-core coil 3 run slightly displaced from the radius in the face regions and, when viewed axially, congruently in the air-gap sections 4', 4". The air-core coils are connected via a support 21 with the hollow axle, the return path surface on the face of the first body is visible, as are the individual magnetic poles of the second body 7, which are backed with a return path body which is ring-shaped when viewed axially.

Fig. 26 shows a further development of the electrical machine in axial section. The air-core coil 3 extends into an air gap 4 which is delimited by first and second drum-shaped bodies 6, 7, with the bodies having an elliptical shape in section. The coil support 21 is led through a slot 11 in the second body 7 out of the air gap region. A

connection of the air-core coil 3 or the field device with the axle 24 or the shaft 1 is not defined.

Fig. 27 shows an electric machine in axial section. The machine consists of three hollow cylindrical bodies 6, 7, which are nested inside each other coaxial to a shaft 1 or axle 24 and delimit an air gap consisting of the air gap sections 4', 4". The air-core coil 3 is folded around one external edge on the face of the first hollow cylindrical body 6, which is a return path, in 18. The outer and inner hollow cylindrical second body 7 consists on the air gap side of permanently magnetic poles 27 which are affixed to a return path. The first and second bodies are securely attached to one another at one face. The air-core coil is connected via a support 21 with the housing 2, with connections with the shaft or axle not defined.

Fig. 28 shows an electrical machine from Fig. 27 in radial section. First and second bodies 6, 7, which are ring-shaped when viewed in the direction of the axle, are visible, and the bent conductor 20 and the inactive conductor, which lies in the direction of movement, of each of the air-core coils 3 are also visible.

Fig. 29 shows an electrical machine in axial section. The machine consists of four hollow cylindrical bodies 6, 7, which are nested inside each other and lie coaxial to an axle 2 or shaft 1 and which delimit an air gap 4 between themselves consisting of the air gap sections 4', 4", 4'", 4"", 4'"", with the air-core coil 3 running through all of the air gap sections, which are each delimited by two surfaces on the shells or faces of the hollow cylindrical bodies. The air-core coil thereby completes two left bends and two right bends.

Fig. 30 shows an electrical machine from Fig. 25 in radial section. The three outer hollow cylindrical bodies are

visible in the axial direction as ring bodies 6, 7, as are the air gap sections 4', 4'", 4'"" delimited by their shells. The air-core coil 3 is visible, above all, in its radial course in the air gap section 4" and, with its inactive conductor, in the outer and inner air gap sections on the shell side, as is the coil support 21 in the region nearest the axle.

Fig. 31 shows an electrical machine in axial section. The machine consists of three hollow cylindrical bodies 6, 7, which are nested in each other coaxial to a shaft 1 or axle 24 and delimit an air gap 4 consisting of the air gap sections 4', 4", 4'", 4"". The air-core coil 3 completes two right bends and a left bend in its course through the air gap sections. A characteristic here is that the first body 6 only has magnetic poles on one side in axial section.

Fig. 32 shows an electrical machine from Fig. 31 in radial section. The two outer hollow cylindrical bodies are visible as ring-shaped bodies 6, 7, as is the inner hollow cylindrical body 7 with its return path surface on its face, as are the air gap sections 4", 4"" delimited by them on the shell side. The air-core coil 3 is visible, above all, in its radial course in the air gap section 4" and, with its inactive conductor, in the outer air gap sections on the shell side, as is the coil support 21 in the region nearest the axle.

Fig. 33 shows an electrical linear machine from Fig. 34 in cross-section. The plate-shaped bodies 6, 7 lie parallel and displaced relative to one another in such a way that they uniformly delimit the parallel air-gap sections 4', 4". The first plate-shaped body 6 is a return path plate, around which an outer edge of the air-core coil 3 lying in the direction of movement is folded at 20 and in which the air-gap sections 4', 4" run. A coil side is visible which

is supported by 21 in the folded region 18. The two plate-shaped bodies 7 contain the magnetic poles 27.

Fig. 34 shows an electrical linear machine from Fig. 33 in cross-section. The course of the air-core coil 3 in the direction of movement and the folded air-core coil parts 20 are visible. Five air-core coils are folded around the first plate-shaped body 6 and run in the air gap sections. The direction of movement is right to left in the plane of the paper.

Fig. 35 shows the electrical linear machine from Figs. 33, 34 in section. The course of the partial coils in the air gap section 4' and the plate-shaped return path of the first body 6, as well as the magnetic poles of the first plate-shaped body 7 lying under it, are visible.

Fig. 36 shows an electrical linear machine from Fig. 37 in cross-section. The linear machine essentially consists of three parallel plate-shaped bodies 6, 7 which uniformly delimit an air gap 4 in which the second plate-shaped body 7 is wrapped around an outer edge lying in the direction of movement at a uniform distance, with the second plate-shaped body having a continuous slot 11 for leading through the coil support 21. The magnetic poles of the plate-shaped first body 6 are electromagnetic, so that the excitation coils belonging to it are inlaid in the grooves of its return path body. The air-core coil 3 is uniformly bent around the plate-shaped first body and runs in the air gap 4 on both sides of the plate-shaped first body, with one coil side visible.

Fig. 37 shows an electrical linear machine from Fig. 36 in section. The partial coils of the excitation coils and the two air-core coils 3 are visible as rotors with their coil support 21 on one side of the plate-shaped first body 6.

The direction of movement is right to left in the plane of the paper.

Fig. 38 shows an electrical linear machine from figs. 36, 37 in section. The bent coil parts of the air-core coils 3 and the excitation coils, which are embedded in the return path of the first body 6, as well as the inactive air-core coil parts of the air-core coil 3 lying in the direction of movement, are visible.

Figs. 39-41 show various exemplary further developments of the folded edge and outer regions of a first and second body 6, 7, with the inner body 6 surrounded by the air-core coil 3, which has the coil support 21 axially outside the air-core coil. In all three embodiments, the return path flat band 5 is affixed to the left second body 7. Magnets belong both to the left and to the right second body 7, while the first body 6 has no magnets 27, or magnets 27 affixed on one side or both sides, and is rounded off in different ways in its outer edge region (also in angular and T shapes), in order to achieve a favorable course of the field lines, which are indicated by lines through the air-core coil.

PART NUMBERS IN THE FIGURES

1 shaft
2 housing
3 coil (open, closed)
4 air gap
4', 4"... air gap sections of the air gap 4
5 outer flat band, preferably a return path flat band, a ring-shaped body when viewed axially
6 first body of the field device (forms the boundary surface of the air gap 4)
7 second body of the field device (forms the other boundary surface of the air gap 4)
8 disk-shaped carrier
9 inner flat band, a ring-shaped body when viewed axially
10 edge of the first body (lies in the direction of movement and is an abutting edge or angle edge
11 continuous slot in the second body
12 pole width
13 bearing
14 coil width
15
16 disk ring
17 electronic sensor
18 folded region
19 return path body of the magnetic poles of the first body
20 conductor in the folded region
21 coil support
22
23 permanent magnet disk
24 axle
25 collector
26 slip contacts
27 magnetic pole
28
29 winding